

Spatial Variations of the Wave, Stress and Wind Fields in the Shoaling Zone

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<http://mist.oce.orst.edu/shoaling/shoaling.html>

LONG-TERM GOAL

Our long term goals are to improve parameterization of surface fluxes in the coastal zone in the presence of wave growth, shoaling, and internal boundary layer development. These goals include improving the present form of similarity theory used by models to predict surface fluxes and stress over water surfaces and documenting development of internal boundary layers in the coastal zone that are currently not modelled correctly, particularly in cases of flow of warm air over colder water.

OBJECTIVES

The long-term goals are to improve parameterization of surface fluxes in the coastal zone in the presence of wave growth, shoaling, and internal boundary layer development. These goals include improving the present form of similarity theory used by numerical models to predict surface fluxes and stress over water surfaces, especially over the coastal zone, and to document development of internal boundary layers in the coastal zone which are currently not modeled correctly, particularly in cases of flow of warm air over colder water.

APPROACH

The first approach is to categorize all of the cases to separate effects of atmospheric internal boundary layers and the shoaling waves on the interaction between the atmosphere and the sea. The second approach is to compare the roughness length behavior with existing formula to study the interaction between the atmosphere and shoaling waves. The third approach is to explore implementation of the modified roughness length formula in numerical models in cooperation with other groups.

WORK COMPLETED

The 1997 Shoaling Experiment was completed in November (Sun et al., 1999) where the NOAA LongEZ examined both the horizontal and vertical structure of offshore flow near Duck, North Carolina. All the instruments on board of the LongEZ operated successfully and their performance is reported in the annual report of Tim Crawford (Contract No. N00014-97-F-0123). The data were processed and quality-controlled at Oregon State University. The data were organized and analyzed (see web page <http://mist.oce.orst.edu/shoal/shoal.html>). All of the flight data along the same flight track and mission were aligned and composited. The correction formula for the wind

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speed as a function of wind direction is tested and used to correct for the measured wind speed. The correction is found to be very important in spiral soundings.

RESULTS

Environmental conditions can be generally divided into on-shore flow of cooler air over warmer water, and off-shore flow of warmer air over cooler water. Based on composited flight data, the stress increases toward the coastline. The increase of the stress is related to the increase of the roughness length toward the coast. For the offshore case, the surface friction velocity decreases gradually toward the open ocean with some oscillation probably due to flux sampling errors. The variation of the averaged surface friction velocity is about 0.1 m/s over the distance of 10 km. The decrease of the surface friction velocity may be partly due to the decreasing influence of the advected turbulence from the land surface and partly due to the decrease of the surface roughness of the wave field toward the open ocean. The latter may be related to increasing wave age and decreasing shoaling activity in the offshore direction.

The influence of the stability of the atmosphere on the stress is demonstrated from one flight, which flew across a warm pool, about 70-km offshore. This warm pool is a branch of the Gulf Stream. The sea surface temperature in the warm pool was about 2 C warmer than the surrounding water. As the cold air flows over the warm pool, fluxes of momentum, heat, and water vapor increase to values larger than that for the surrounding region. The friction velocity increases by about 0.06 m/s that is comparable with the variation of the friction velocity over the shoaling zone. The smaller surface roughness length over the warm pool compared to the surrounding area indicates that the increase of the fluxes is caused by the increased instability instead of increased surface roughness associated with the shoaling waves. This result implies that the effect of small-scale changes of atmospheric stability in the coastal zone is as important as the flux variation as the shoaling wave field. Over the water surface, the stress is very small compared to typical values over land. Therefore, relatively weak sensible heat flux can lead to significant instability effects since the stability, z/L , is inversely proportional to the cube of the surface friction velocity. The small marine friction velocity leads to enhanced sensitivity to the heat flux.

Fluxes of momentum and heat and the air temperature are much higher over the land surface than those values over the water surface on both sides of the Outerbank. The average friction velocity over the open water is about 0.1 m/s higher than that over the inland water. The difference between the open ocean and inland water is partly due to the greater roughness of the sea surface compared to that for the relatively smooth inland water and partly due to the difference in the atmospheric stability associated with the different water temperatures.

The relationship between the stress and the normalized radar cross section from the on-board Ka-band radar as a function of offshore distance is still under investigation. Doug Vandemark has found a reasonable correlation between the mean squared slopes derived from the radar and derived from three lasers. The two-dimensional wave spectra derived from the three lasers are being processed jointly by Mark Donelan at the University of Miami, Jielun Sun at NCAR, and Chris Vogel at NOAA/ATDD.

IMPACT/APPLICATION

The results from the November 1997 shoaling experiment suggest that numerical models require substantial improvement before they can approximate offshore flows, particularly in the case of stable flows due to warm air advection over cooler water. The results of this fieldwork also suggest modifying the spring experiment plan to include more repeated soundings at the same location and include flights inland to better understand the total mesoscale circulation system, which influences the coastal zone.

PUBLICATIONS

Mahrt, L., Dean Vickers, J. Sun, Timothy Crawford, Chris Vogel and Ed Dumas, 1999: Coastal Zone Boundary Layers. 13th Symposium on Boundary Layers and Turbulence. American Meteorological Soc. Dallas.

Sun, J., L. Mahrt, Dean Vickers, John Wong, Tim Crawford, Chris Vogel and E. Dumas, 1999: Air-sea interaction in the coastal shoaling zone. 13th Symposium on Boundary Layers and Turbulence. American Meteorological Soc. Dallas.